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ECOLOGICAL STUDIES ON THE JELLY-FISH, AURELIA AURITA (LINNE), IN URAZOKO BAY, FUKUI PREFECTURE -XI. AN OBSERVATION ON EPHYRA FORMATION

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**ECOLOGICAL STUDIES ON THE JELLY-FISH, *AURELIA AURITA*
(LINNÉ), IN URAZOKO BAY, FUKUI PREFECTURE—XI.
AN OBSERVATION ON EPHYRA FORMATION**

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With Text-figure 1

Although many studies are noted on the asexual reproduction of *Aurelia aurita* polyp (e.g. Agassiz 1862, Haeckel 1881, Percival 1923, Gilchrist 1973, Verwey 1942, Berrill 1949, Hirai 1958, Kakinuma 1961, 1963, Custance 1964, 1966, 1967, Spangenberg 1965, 1967a, 1968, 1971, Thiel 1962, 1966, Chiba 1969), the direct development from fertilized eggs or planulae to single ephyrae has been reported very rarely.

So far as the writer is aware, such a case has been referred to only in a few short reports by Haeckel (1881), Berrill (1949), Hirai (1958) and Spangenberg (1967a, 1968), but seemingly no detailed studies have ever been made on this phenomenon.

In the course of ecological studies on the jelly-fish, *Aurelia aurita*, in Urazoko Bay, Fukui Prefecture, some laboratory experiments were carried out to see how the fertilized eggs or planulae develop to ephyrae under the natural condition. From the results obtained, the writer was able to learn the days needed to ephyra liberation and the ratio between the normal polyp formation and the direct ephyra liberation without regular polyp formation and strobilation.

In preparing this paper, the writer is grateful to Prof. T. Tokioka of the Seto Marine Biological Laboratory, Kyoto University, Prof. H. Ohmi of the Hokkaido University and Prof. Y. Sugiura of the Dokkyo University for their kindness in presenting suggestion and in reading the manuscript critically. Thanks are also due to Dr. Y. Kakinuma of the Asamushi Marine Biological Station, Tôhoku University and Dr. S. Nishimura of the Seto Marine Biological Laboratory, Kyoto University for their invaluable advices and suggestions in the course of this study.

Material and Method

In March to June, 1971 and April to June, 1973, mature medusae of 15 to 30 cm in bell-diameter were collected by a hand-net from Urazoko Bay, a small cove of Wakasa Bay on the Japan Sea coast (Yasuda 1971). Fertilized eggs or planulae attached to their oral-arms or sub-umbrella were gathered by using a syringe and

immediately transferred to a small tank (50 cm \times 30 cm wide and 30 cm deep) with upper shells, 5 cm long \times 5 cm high, of *Pecten albicans* laid on the bottom, or to five 3-liter beakers each containing three of the same shell. In the 1971 experiment, planulae collected from two or three medusae had been mixed before they were transferred to respective vessels, while in the 1973 experiment planulae obtained from respective medusae were transferred separately to different vessels. Counting of polyps and ephyrae was done under a microscope of lower magnification. Polyps or ephyrae were reared in natural sea water, with weak aeration, and fed with a rotifer, *Brachionus plicatilis* twice a day. The water temperature and chlorinity were checked every day at 14:00–15:00.

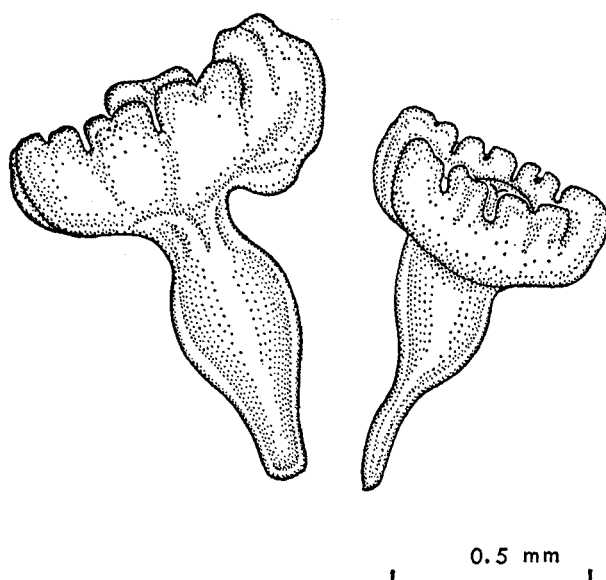


Fig. 1. Direct development from planulae to single ephyrae

Results and Discussion

Days needed to Ephyra Liberation: A stage of direct development from planulae to single ephyrae is shown in Fig. 1, and the relation between the days necessary from planula settling to ephyra liberation and the water temperature in the direct development from planulae to single ephyrae may be seen in Table 1. The table shows that the days to the ephyra liberation are 3 to 4 days at the water temperature 20–28°C, 5 days at 15–21°C, 7 to 8 days at 12–15°C, and 8 to 11 days at 6–12°C.

Thus, evidently the higher the water temperature is, the sooner the ephyra liberation will come. The ephyra liberation in the direct development was done nearly simultaneously in a short time, so that the vessels were often filled of ephyrae liberated from the shell surface on the bottom in a few to several days after planula settling. On the other hand, the strobilation of polyps normally developed from

Table 1. Relation between the days needed from settling to liberation and the water temperature in direct development of planula to single ephyrae.

Date of observation	Water temperature(C°)		Chlorinity range (%)	Days to ephyra liberation
	Range	Mean		
Mar. to June, 1971	6.5-12.1	9.2(± 1.8)	17.6-18.6	8-11
	11.6-14.7	13.0(± 1.2)	18.2-18.8	7-8
Apr. to June, 1973	15.0-21.4	18.3(± 1.8)	18.1-18.3	5
	19.8-24.6	21.6(± 2.6)	18.2-18.3	3-4
	22.8-27.8	24.7(± 2.9)	17.9	3

planulae occurred 1 month or over after planula settling at 6-27°C. Further, it occurred sporadically, but never simultaneously at least during the writer's experiments. These observations will be reported in detail in further papers. The chlorinity ranged from 17.6 to 18.8‰ during the experiments, but maintained steadily nearly 18‰ except in the case of rearing at 6 to 12°C.

Number and Ratio of Polyps and Ephyrae developed from Planulae obtained from the Same Single Medusae: Planulae liberated from mature medusae and attached to the shell surface developed soon to regular polyps or directly to ephyrae. Number of polyps and ephyrae in respective beakers are given in Table 2. In the pursuit of planulae from 15 to 26 cm medusae obtained in April, ephyrae developed directly from planulae predominated over polyps, the percentage of ephyrae to the total of polyps and ephyrae was 65.4 to 88.3% with the mean of 76.1%. The same tendency is again confirmed in the next observation of the planulae obtained from medusae 20 to 30 cm in bell-diameter in May except only the material from a 20 cm medusa. The percentage of ephyrae ranged from 48.1 to 68.2%, with the mean of 62.7%. The last observation was made on planulae from medusae of 15-20 cm in bell-diameter which were collected in late June when it was rather difficult to obtain mature medusae. This time, the number of polyps predominated over that of ephyrae in the two cases of 19 and 15 cm medusae, though in three other cases ephyrae were more numerous than polyps. The percentage of ephyrae ranged from 36.0 to 75.0% and with the mean of 57.4%.

The writer has already suggested in his previous paper (Yasuda 1971) about the spawning season of *Aurelia* in this region by checking the existence of fertilized eggs or planulae on the oral-arms or sub-umbrella in a year from April 1969 to April 1970. And it was confirmed that the spawning season extended from January to June, in the water temperature range of 8-19°C, and with the peak in January to May in the temperature range of 8-18°C. Kon and Honma (1972) have reached the same conclusion by histological examination of the gonad of this medusa. On the other hand, the writer showed, on monthly sampling by a plankton-net in a year-round study from November 1966 to October 1967, that the occurrence of *Aurelia* ephyrae continued from middle January to late June in the water temperature range of 8-22°C, with the peak in April in the temperature range of 11-14°C (Yasuda 1968). Further, it was mentioned that ephyrae were collected in Nyu-ura Bay in early February to late

Table 2. Number and percent of polyps and ephyrae developed from the planulae obtained from the same single medusae.

a) Observation made four days after planula settling on April 11, 1973

Bell-diameter of parent medusae	Number of planulae studied	Developed to polyps (%)	Developed directly to ephyrae (%)
15 cm	301	104 (34.6)	197 (65.4)
18 cm	315	72 (22.9)	243 (77.1)
22 cm	175	54 (30.9)	121 (69.1)
24 cm	484	149 (30.8)	335 (69.2)
26 cm	606	71 (11.7)	535 (88.3)

b) Observation made three days after planula settling on May 15, 1973

Bell-diameter of parent medusae	Number of planulae studied	Developed to polyps (%)	Developed directly to ephyrae (%)
20 cm	54	28 (51.9)	26 (48.1)
21 cm	35	15 (42.9)	20 (57.1)
23 cm	85	27 (31.8)	58 (68.2)
23 cm	191	69 (36.1)	122 (63.9)
30 cm	40	12 (30.0)	28 (70.0)

c) Observation made two days after planula settling on June 25, 1973

Bell-diameter of parent medusae	Number of planulae studied	Developed to polyps (%)	Developed directly to ephyrae (%)
15 cm	34	18 (52.9)	16 (47.1)
18 cm	72	18 (25.0)	54 (75.0)
19 cm	50	32 (64.0)	18 (36.0)
20 cm	26	8 (30.8)	18 (69.2)
20 cm	36	17 (47.2)	19 (52.9)

June in 1965–1966 (Yasuda 1969). The writer's unpublished data includes the record that the appearance of ephyrae in this region was not yet confirmed on January 20, but recognized on February 12 in 1970. In short, the spawning of *Aurelia* and the occurrence of ephyrae are seen nearly in the same season or the latter will surely be seen within a month after beginning of the former.

The development of the egg of *Aurelia*, the stages from planula to strobila and the release of ephyrae were reported as follows. In Japanese waters, Hirai (1958) reported that it needed 3.3 months after planula settling in the laboratory experiment to see the ephyra release by strobilation at Asamushi in northern Honshu.

In northern waters of Europe, Thiel (1962) made a detailed field observation in Kiel Bay and found that the stages from planula settling to ephyra release by strobilation extended over 4 months. If such a long developmental period were required in Urazoko Bay, too, the appearance of ephyrae would be seen three or four months after the beginning of the spawning season. There, however, ephyrae appear actually just after the setout of spawning. As seen in Tables 1 and 2, most of the planulae obtained

around the peak of the spawning season in this region develop directly into ephyrae and the ephyra liberation is done explosively within eleven days after planula settling even at the water temperature below 10°C.

On the contrary, the strobilation is found sporadically over a month after planula settling. From these facts, it may be concluded that most ephyrae collected in Urazoko Bay are probably produced by the process of direct development from planula, and that the production of ephyrae by the popular formal process from planula settling through strobilation is only supplementary in this region.

According to the laboratory observation made by Spangenberg (1967a, 1968), small starved polyps usually produced only one ephyra. In the present experiment, however, polyps were fed with dense *Brachionus plicatilis*. Also in the natural environments, rich zooplankters such as copepods (*Paracalanus*, *Acartia*) and cladocerans (*Penilia*, *Evadne*) were densely found in this region throughout the spawning season of *Aurelia* and the occurring months of ephyrae (Yasuda 1969).

Therefore, the prevalence of the direct development of planulae to ephyrae in this region can not be considered to be caused by shortened nutrition. The mature eggs of *Aurelia aurita* in Urazoko Bay are 0.26–0.30 mm in diameter (Kon and Honma 1972) and this seems a little larger than in the European forms. The prevalence of the direct development might be related to the larger egg size as suggested by Berrill (1949)¹⁾.

Summary

In March to June, 1971 and 1973, fertilized eggs or planulae obtained from mature medusae of *Aurelia aurita* collected from Urazoko Bay on the Japan Sea coast were reared experimentally in natural sea water by feeding them with a rotifer, *Brachionus plicatilis*. Larger parts of the planulae developed directly into ephyrae, and the ephyra liberation occurred explosively 3 to 11 days after the planula settling. Evidently, the higher the water temperature is, the sooner the ephyra liberation will come. The ephyra production by regular strobilation seems to be only supplementary in Urazoko Bay.

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1) According to Berrill (1949), the egg size of *Aurelia aurita* is very variable, ranging from 0.15 to 0.23 mm in diameter, and the largest planulae develop directly into ephyrae.

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* Referred to indirectly.